

Technology Advancements Enhance Aircraft Support of Experiment Campaigns

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Abstract: For over 30 years, the NASA Airborne Science Program has provided airborne platforms for space bound instrument development, for calibrating new and existing satellite systems, and for making in situ and remote sensing measurements that can only be made from aircraft. New technologies have expanded the capabilities of aircraft that are operated for these missions. Over the last several years a new technology investment portfolio has yielded improvements that produce better measurements for the airborne science communities. These new technologies include unmanned vehicles, precision trajectory control and advanced telecommunications capabilities. We will discuss some of the benefits of these new technologies and systems which aim to provide users with more precision, lower operational costs, quicker access to data, and better management of multi aircraft and multi sensor campaigns.

Keywords: *airborne science, trajectory control, situational awareness*

Introduction

Since its introduction in the '70s, the Airborne Science program has provided NASA and its sponsored scientists with airborne platforms to conduct instrument testing and calibration, in situ and remote sensing measurements, and satellite calibrations. This support is provided through an array of aircraft that cover a wide range of range, altitude and endurance capabilities. Over time, upgrades to these platforms have helped the Science community to improve its data collection capability. Additionally, new aircraft systems have helped cover some of the areas that older platforms could not achieve.

The airborne science business is in a simple view a provider of air transport for sensors and instruments. From a systems perspective, NASA's airborne science personnel develop and operate decision support information services comprised of a continuously changing set of instruments and component systems on suborbital platforms. These services appear on the ground and in the platforms. NASA's airborne science program is part of the

emerging global earth observing system of systems. Over time, the systems we develop evolve toward ever-greater levels of trustworthiness and autonomy.

The vision for NASA's airborne science program includes a web-based infrastructure that delivers useful information to decision-makers in a timely fashion. This includes near realtime connectivity between any airborne sensor and the researcher or other decision maker, wherever they happen to be located. An affordable over-the-horizon telepresence capability to and from airborne science platforms has been enabled in recent years via a system called the Research Environment for Vehicle-Embedded Analysis on Linux (REVEAL).

Two new uninhabited aircraft systems – IKHANA and Global Hawk – have been introduced to close gaps in performance envelopes needed for increased on-station measurement durations. The ER-2 and the DC-8 are representative of the suite of manned platforms that have upgraded data systems. The G-III is a new platform in the airborne science fleet and provides a new precision trajectory autopilot suitable for repeat pass interferometry. These vehicle systems and the aforementioned REVEAL capability are described further in this paper.

REVEAL

The Research Environment for Vehicle Embedded Analysis on Linux, or REVEAL, began as an internal project at NASA Dryden to evaluate the feasibility and benefits of using Linux as a network-resident data system (Sorenson, 2003). Today, REVEAL-based data systems have been installed in all Airborne Science's core aircraft. REVEAL includes communications links that enable data to flow in both directions between ground systems and the instrument payload network. Experimenters and ground support personnel can now have more precise situational awareness of the aircraft. When overlaid in Google Earth, users can view the location of the aircraft and its track with real time latencies on the order of a few seconds.

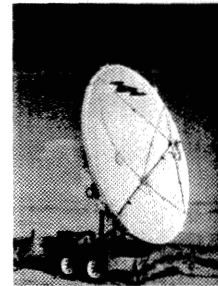
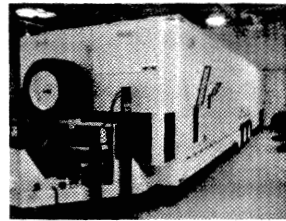
Experimenters can access and assess the behavior of their instruments directly from their offices. As

an experimenter, knowing the ground track of the aircraft and the conditions surrounding the aircraft, corrections in heading or altitude allow for more accurate data gathering and opens the ability to adjust observations based on real time information. Although the system does not provide the bandwidth to download all the data captured, it does allow the users to make adjustments and corrections to either the instrument or the aircraft trajectory to ensure the success of the mission and to make the most of each data gathering opportunity (Freudinger09). We will offer more specific examples as we review the impact of this system on each aircraft we support.

Ikhana (Predator B)

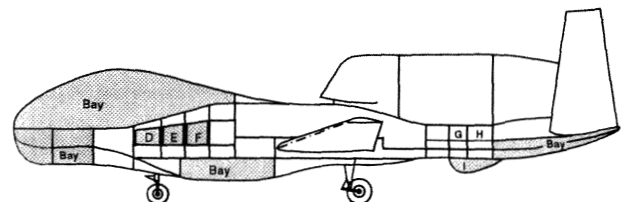
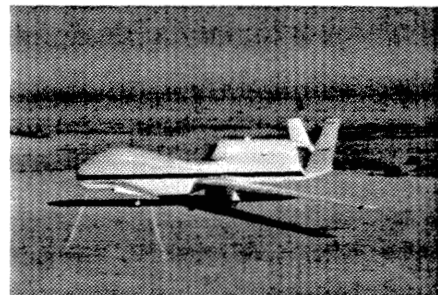
The Ikhana aircraft is a modified version of the Predator B produced for the Air Force. It was acquired by NASA in 2006 to support aeronautical and science research. The aircraft was modified to accommodate science payloads that require long loiter times or access to remote locations that would endanger a crew required by manned aircraft operations. Several modifications were made from the Air Force model to accommodate additional payload capabilities, on board recording for payloads, onboard GPS time delivered to nose bay and/or any pylon location via e-net or other protocols, custom pylon and pod ready to fly, and an independent Line-Of-Sight data link for payloads (currently limited to ~1Mbps). It also has separate command and control functions for the aircraft and the payload.

With its removable wings, the Ikhana can be transported anywhere in the world. The mobile ground station and antenna can support the aircraft from any location. The new communication links allow for beyond line of sight coverage.



Global Hawk

NASA was able to acquire two of the ACTD aircraft used during the development of the UAS capability for the Air Force. The new platform expands the Airborne Science high altitude capability in conjunction with the ability to support missions without putting crew members at risk. In partnership with Northrop, NASA is converting the aircraft to enable support of Science work. Modifications include the removal of classified equipment, separation of the command and control functions from the payload control instruments, different communication equipment and capabilities, and expanded payload capacity.



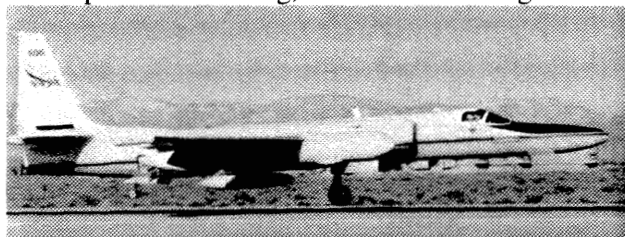
The REVEAL system will be used to provide continuous experimenter access to science instrumentation. In addition to providing a near-real time look at the measurements, this capability also provides confidence that the various sensors are functioning properly. Considering that the Global

Hawk can fly for over 30 hours on a single mission, the ability to monitor the health of the experimental systems is critical to efficient use of the aircraft.

The details of the NASA Global Hawk capabilities and concept of operations will be covered in greater detail in a paper presented by Mr. Chris Naftel titled **NASA Global Hawk: A New Tool for Earth Science Research.**

ER-2

In line with high altitude support, NASA operates two ER-2 aircraft, sister aircraft to the Air Force's U-2. The ER-2 has been supporting the Science community for over 25 years. For years, the ER-2's have been known for their ability to carry significant payloads at high altitudes for extended periods of time. With both pressurized and unpressurized compartments, the ER-2 is ideal for satellite calibration missions, satellite instrument development and testing, and remote sensing.



The aircraft is now equipped with the REVEAL system. This new system allows experimenters to assess the health of their instruments on board to ensure proper operation and in many cases be able to fix problems while in flight. In the past, experimenters using the ER-2 were limited in their ability to manipulate their instrument. Now, data samples can be downloaded while in flight to ensure the equipment is functioning as expected. Last summer, while operating a long duration flight with the AVIRIS instrument, Airborne Visible/Infrared Imaging Spectrometer, the operator noticed anomalies in the images being captured. He contacted the pilot and requested a reset of the instrument. The reset was successful, salvaging the flight.

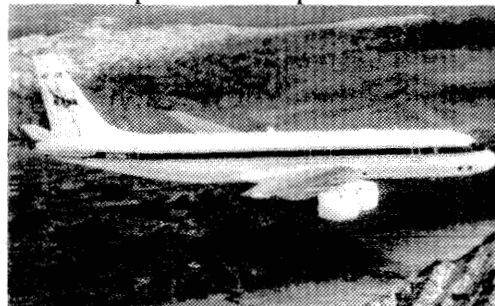
REVEAL, in conjunction with the navigational system, provides the experimenter and support personnel on the ground with more accurate aircraft

situational awareness. The enhanced capability has helped experimenters improve their data gathering opportunities by providing the pilot with course corrections in flight as well as improving the safety of flight as pilots can be advised of problem areas before they fly into them. Upgrades in the communication suite of the aircraft provide greater access and reliability to communicate with the pilot while in flight. As easy as making a phone call, the experimenter can call the pilot and review mission targets, duration, instrument health, course corrections, and other issues.

During the TCSP (Tropical Cloud System and Processes) campaign, the upgrades to the aircraft were put to the test. The mission required that the ER-2 fly over hurricanes as they developed and traveled through the Gulf of Mexico. The experimenters had Hurricane Emily, one of the most powerful storms of our times. As the pilot, Dave Wright, flew the aircraft over the storm, experimenters and ground crew were in constant communication with him, making course adjustments, avoiding dangerous areas, and acquiring data never before obtained in hurricane research.

DC-8

The DC-8, one of the oldest and most reliable flying laboratories, has also benefited from system upgrades implemented over the last few years. The aircraft can carry numerous instruments on the same flight and still accommodate a large number of experimenters and operators in a shirt-sleeve environment. As a result, the airplane can support large, complex, developmental instruments that require continuous operator attention. It also provides a collaborative environment in which scientists can compare and correlate measurements from multiple sensors exposed to the same air mass.



The DC-8 was outfitted with a new navigational recording system which in combination with REVEAL provides detailed flight parameters. In addition, with the new wiring and network capabilities, the aircraft now has X-chat which allows the experimenters in the DC-8 to communicate and exchange data among themselves and with those in the ground. With the enhanced situational awareness provided by REVEAL and viewed through X-chat in the cabin, experimenters can request course changes, turns and changes in altitude that enhance their data gathering and maximize the use of the aircraft to fly to the areas where the data resides with more accuracy, wasting little flight time.

During the ARCTAS campaign (Arctic Research of the Composition of the Troposphere from Aircraft and Satellites), the upgrades displayed their benefits, especially when coordination between aircraft was required for simultaneous measurements. The Wallops P-3B, which has also been outfitted with REVEAL and X-chat, was on a coordinated flight with the DC-8. Experimenters in both aircraft observed how the tracks of both aircraft converged over the target area ensuring that the data collected by all instruments would be valid for comparison purposes.

G-III

A new platform to the Airborne Science family, the G-III was acquired from the Air Force and dedicated to the development of the new generation Synthetic Aperture Radar, called UAVSAR, and the Platform Precision Autopilot, known as the PPA. As the name suggests, the UAVSAR was meant to bring the SAR technology in line with the size and weight limitations of the uninhabited aerial vehicles, UAV for short.



The most notable advancement in technology is the introduction of the PPA. The PPA controls the aircraft guidance system ensuring that the aircraft flies within a 10m tube, allowing it to fly over the same location at different times. The precision pass technology allows the scientists to compare similar observations at different time intervals and compare changes in the surface over time. For more details, please refer to Mr. Paul A. Rosen's paper, **UAVSAR: A New NASA Airborne SAR System for Science and Technology Research, 2006.**

Summary

For over 30 years, the Airborne Science program has provided platforms to support the Science community. This support is predicated on our ability to provide the scientists with the right lift in the right places. Technological developments have improved our ability to provide that support. From REVEAL to the PPA, scientists can now target more specific locations, make real time adjustments to flight tracts, review the health and performance of their instruments and preview the results of their efforts without ever leaving their office. Furthermore, the ability to coordinate aircraft and sensors in flight will provide additional opportunities for data collection and comparability. Finally, the ability to adjust flights and monitor instruments will improve performance, reliability and reduce costs, as flight time waste will be minimized. Such efforts will continue to improve the support provided by Airborne Science in the future.

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